AVERAGE HEATING VALUES OF AMERICAN COALS BY RANK AND BY STATES

BY GEORGE J. FLYNN, JR.

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INTRODUCTION

The Bureau of Mines receives and answers many requests for information on the qualities and properties of American coals, and also publishes many papers that deal with coal characteristics. Compilations of chemical analyses of coal from specific locations are contained in a series of technical papers,[2] by States, whereas typical analyses of coal seams, by States and counties, are given in data books, volumes 1 to 7,[2] by producing districts, as defined in the Bituminous Coal Act of 1937. Bulletin 446, "Typical Analyses of Coals of the United States," condenses and supplements these data books, which do not apply to the Western States. Other coal properties are described in numerous publications listed in the Bureau of Mines Bibliography of Publications. However, no recent publication lists average B.t.u. values by rank on a State-wide and national scale. Averages have been estimated in the past, and some of them are included in this paper for comparison.

RESULTS OF CALCULATIONS

The average and the ranges of as-received B.t.u. values of American coals on a Nation-wide basis, as found by the statistical method described in this paper, are given in table 2 and on a State-wide basis in table 3. The following is abstracted from table 2:

Rank	Average as-rec'd B.t.u. content
Anthracite (Pennsylvania only)...........	12,750
Bituminous (all).........................	13,100
Low-volatile bituminous..................	14,200
Medium-volatile bituminous...............	14,000
High-volatile bituminous.................	12,900
Subbituminous............................	9,550
Lignite..................................	7,000
All ranks................................	13,000

EVALUATION OF POSSIBLE METHODS

In deriving average B.t.u. values for coals, the results depend on the type of data available and the methods of calculation. The data, or analyses, may represent any of three types of samples - mine, tipple, or delivered. In mine sampling, a channel cut is made of a vertical face of the coal bed, carefully excluding most of the impurities, and the material retained is the sample. It is readily seen that mine samples are selected samples and do not strictly represent the unmined coal bed, unless the coal contains no major impurities. Mine samples generally represent the best-quality coal that could be produced. In contrast to mine samples, tipple and delivered samples represent coal that actually has been mined, and their analyses may show either lower or higher values than mine samples of the same coal, depending on treatment and preparation after mining.

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[2] See page 10.

Of the thousands of analyses accumulated by the Bureau of Mines, most are of either tipple or delivered samples and represent the coal after it has been mined. Any average calculated from this aggregate of data will, consequently, reflect coal that has been produced, and not unmined coal in situ.

The method of calculating an average from the basic data also will have considerable influence. If there are three seams of coal in a county, the average analysis for the county is not necessarily the arithmetic mean of analyses of the three individual seams. For a probable average of unmined coal, the B.t.u. values of each seam should be weighted in proportion to the unmined reserves of each seam. In similar manner, an average for past production should be weighed according to the past production for each seam. Figures for coal reserves are only estimates based upon geologic evidence and its interpretation. Production records are much more accurate than estimated reserves, although detailed production records for individual seams by counties are very few.

Technically, the most accurate method would be to derive a county average for each rank of coal by weighting the B.t.u. value for each seam by its production in tons. The county averages would then be weighted according to the total production for each county to obtain a State average. Similarly, a national average for each rank would be computed from the State averages by weighting them according to the State production.

Unfortunately, detailed production records for the seams within a county are not available, except in Alabama, Maryland, Ohio, and West Virginia.

METHODS USED IN THIS PAPER

The typical "as-received" B.t.u. value for individual coal seams by rank and by counties was taken from Bulletin 446 and Data Book 7. (This Data Book, which covers Iowa, Missouri, Kansas, Arkansas, Oklahoma, and Texas, contains data not available when Bulletin 446 was originally compiled.) If there were more than one seam of coal of the same rank within a county, the arithmetic mean of the several B.t.u. values was taken as representative of that county. This typical B.t.u. value was then weighted (multiplied) by the production in tons for that county in 1944, as given in the Bureau of Mines Minerals Yearbook. The sum of the products obtained was divided by the total State production, which gave the average "as-received" B.t.u. for the State. Similarly, the average for each State was weighted according to its production,

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and the national average for each rank of coal was determined. In some instances, counties within a State had no analyses but reported production, and vice versa. Such counties were omitted. If a coal seam exhibited two or more ranks within a county, an attempt was made to split the seam accordingly, if feasible; if not, it was not considered. These instances were few and relatively insignificant. To show Pennsylvania anthracite on the same run-of-mine basis as the other coals, its various sizes (egg, stove, etc.), by regions, were consolidated to a run-of-mine basis by first weighting the average B.t.u. content of each size by its percentage of total production for 1944, as given in the Minerals Yearbook. The regional averages were then calculated for a State average.

COMPARISON OF METHODS

One weakness of the method used has already been discussed on page 2. In using the arithmetic mean as the average of all the coal seams in a county, there is a possibility of serious error. Such an error will reflect approximately the range of the seam averages, for the arithmetic mean may be greatly distorted by extreme values.

Comparison of the most accurate method, technically, and the method used in this paper was made for the four States for which production records by seams for each county were available. The results, rounded to the closest 10 B.t.u., are shown in table 1.

The national averages were then redetermined, using the averages shown in method 2 of table 1. There was no appreciable difference in the national averages, but the second compilation, in which the more accurate averages were used, for these four States, was retained. For all other coal-producing States, method 1 of table 1 was used from necessity. The national averages by rank, rounded to the closest 50 B.t.u., are listed in table 2, column 1. Columns 2, 3, 4, and 5 are values published in previous years and are shown here for comparison.

STATE AVERAGES

Table 3 lists the State averages used in compiling the national averages of table 2. For comparison, a somewhat similar list compiled about 10 years ago is shown in column 2. However, the averages in column 2 of table 3 are based upon analyses of mine samples exclusively, although they were calculated by weighting representative analyses by counties according to the production of each county at that time (1936).

DISCUSSION OF RESULTS

In addition to the limitations imposed by the lack of production data (see table 1), the averages in tables 2 and 3 do not purport to show the B.t.u. content of a particular coal. Individual analyses of specific coals or sizes of coals may be higher or lower than the values indicated in table 2. It should be emphasized that the averages compiled are approximations of the heat content of the various ranks of coal that have been produced in the United States.

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Undoubtedly, tables 2 and 3 will be revised when newer typical analyses are compiled, as the quality of mined coal will fluctuate over a period of years. A "buyer's market" will tend to raise the quality of coal produced, whereas in a "seller's market" (for example, World War II), ash content increases and heat value decreases. A similar effect could be produced by exhausting the better coals in a mining district and subsequently producing from dirtier coal beds. It has been estimated that the ash content of coal used as locomotive fuel by one railroad increased from 8 to 10 percent in 1940 to 12 to 14 percent in 1947.3/ Deterioration in quality also has been reported for various raw coals from the Raton Mesa region of Colorado and New Mexico, where ash content has increased from approximately 13 percent in 1940 to 18 percent in 1947. This has so affected the washing of these coals that the ash content of washed coal has risen from 9 percent in 1940 to 11 percent in 1947,4/ In contrast, a comparison of Illinois coals, both raw and washed, from 1912 to 1947 indicated no significant changes.5/ Although these and other considerations are recognized, it is beyond the scope of this paper to attempt any practical evaluation of them.

3/ Payne, Earl C., Coal on the Locomotive Front: Coal Age, December 1947, pp. 74-78.

4/ Price, J. D., and Bertholf, W. M., Coal Washing in Colorado and New Mexico: A.I.M.E. Tech. Paper 2548F, Mining Engineering, vol. 1, No. 4, April 1949, pp. 99-108.

5/ Fraser, Thomas, and Crentz, William L., Effect of Mechanical Mining on Preparation Plant Product: Min. Cong. Jour., December 1948, pp. 41-43.

TABLE 1. - Comparison of methods used for State averages

State	Rank	Method 1 1/ Av. "as rec'd." B.t.u.	Method 2 2/ Av. "as rec'd." B.t.u.	Difference in B.t.u.; method 2 compared to method 1
Alabama	Med.-vol. bit.	13,500	13,930	+430
	High-vol. bit.	13,430	13,220	-210
	All bit.	13,440	13,230	-210
Maryland	Low-vol. bit.	13,460	13,750	+290
	Med.-vol. bit.	13,320	13,440	+120
	All bit.	13,400	13,630	+230
Ohio	High-vol. bit.	12,560	12,640	+80
West Virginia	Low-vol. bit.	14,340	14,380	+40
	Med.-vol. bit.	14,320	14,410	+90
	High-vol. bit.	13,790	13,720	-70
	All bit.	13,970	13,950	-20

1/ Based upon arithmetic mean of typical values within county.

2/ Calculated by weighting typical values of each seam by its production by counties. Production data taken from:

(a) Alabama, Annual Statistical Report, Fiscal Year 1943-1944, Dept. of Industrial Relations, p. 108.

(b) Twenty-third Annual Report of Maryland Bureau of Mines, Calendar Year 1945, p. 13.

(c) State of Ohio, Annual Coal Report and Non-Metallic Report, 1945, pp. 20-21.

(d) State of West Virginia, Annual Report of the Department of Mines, 1945, pp. 140-142.

TABLE 2. - As-received B.t.u. averages of American coals

	1*		2		3		4		5	
Rank	Average	Range**	Average	Range	Average	Range	Average	Range	Average	Range
Anthracite***....	12,750	12,500-12,850	13,300	-	12,700	-	-	12,700-13,830	12,700	-
Bituminous (all).	13,100	9,950-14,200	-	11,000-14,400	13,700	-	-	10,040-14,490	-	-
Low-vol. bit...	14,200	13,450-14,400	-	-	-	-	-	13,120-14,860	14,000	-
Med-vol. bit...	14,000	13,300-14,400	-	-	-	-	-	-	-	-
High-vol. bit.	12,900	9,950-14,050	-	-	-	-	-	-	13,500	-
Subbituminous....	9,550	8,350-10,400	-	7,000-11,000	9,500	-	-	8,300-11,230	9,500	-
Lignite.........	7,000	6,600- 7,850	-	6,000- 7,500	6,700	-	-	5,650- 8,000	6,700	-
All ranks	13,000									

1 - Values calculated for this paper.

2 - U. S. Dept. of Commerce, The Coal Industry of the World: 1930, pp. 8-10.

3 - Energy Resources and National Policy, 1939, pt. 2, sec. I, chap. I, Coal Reserves, p. 281.

4 - Mechanization, Employment, and Output per Man in Bituminous Coal Mining: W.P.A. Reprot No. E-9, vol. I, p. 51.

5 - Fieldner, A. C., The National Fuel Reserves: Mech. Eng., March 1947, p. 222.

*Averages rounded to closest 50 B.t.u.
**Range of individual State averages, except for anthracite.
***Pennsylvania only, including Sullivan County.

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TABLE 3. - Average "as received" B.t.u. values, by States

State	Rank	1		2**
		Av. B.t.u.	Range*	
Alabama	Med.-vol. bit.	13,930	13,520-13,980	-
	High-vol. bit.	13,220	12,290-14,430	-
	All bit.	13,230	12,290-14,430	13,750
Arizona	Subbituminous	10,410	-	-
Arkansas	Low-vol. bit.	13,780	13,360-14,140	13,990
Colorado	High-vol. bit.	12,420	11,470-13,230	11,260
	Subbituminous	10,210	8,650-11,510	
	Lignite	7,130	6,700- 7,550	
Georgia	Low-vol. bit.	14,080	13,900-14,250	-
Illinois	High-vol. bit.	11,250	10,500-13,030	11,410
Indiana	High-vol. bit.	11,520	11,350-11,730	11,730
Iowa	High-vol. bit.	9,940	9,360-10,780	10,790
	Subbituminous	9,160	-	
Kansas	High-vol. bit.	12,340	11,170-13,500	12,850
Eastern Kentucky	High-vol. bit.	13,680	12,790-13,880	13,950
Western Kentucky	High-vol. bit.	12,160	10,830-12,780	12,250
Maryland	Low-vol. bit.	13,750	12,600-13,970	-
	Med.-vol. bit.	13,440	13,080-13,640	-
	All bit.	13,630	12,600-13,970	13,630
Michigan	High-vol. bit.	11,500	-	11,780
Missouri	High-vol. bit.	11,320	10,040-12,800	11,640
Montana	High-vol. bit.	10,650	10,210-10,870	9,690
	Subbituminous	8,900	8,580- 8,970	
	Lignite	6,590	-	
New Mexico	High-vol. bit.	12,410	10,550-13,070	12,280
	Subbituminous	9,520	-	
North Dakota	Lignite	6,990	6,400- 7,590	6,980
Ohio	High vol.-bit.	12,640	11,440-12,960	12,760

TABLE 3. - Average "as received" B.t.u. values, by States (Cont'd.)

		1		2**
State	Rank	Av. B.t.u.	Range*	
Oklahoma	Low-vol. bit.	13,640	-	13,430
	Med.-vol. bit.	14,210	-	
	High-vol. bit.	12,710	11,390-13,730	
	All bit.	12,910		
Oregon	Subbituminous	8,960	-	-
Pennsylvania	Anthracite	12,730	12,510-12,840	13,300
	Low-vol. bit.	13,460	12,320-14,010	-
	Med.-vol. bit.	13,780	13,420-13,850	-
	High-vol. bit.	13,460	12,650-13,870	-
	All bit.	13,520	12,320-14,010	13,950
Tennessee	High-vol. bit.	13,460	12,880-13,940	13,820
Texas	Lignite	7,860	7,630- 8,090	7,600
Utah	High-vol. bit.	12,970	10,390-13,040	12,900
Virginia	Low-vol. bit.	12,000	-	-
	Med.-vol. bit.	14,410	14,380-14,440	-
	High-vol. bit.	14,030	13,500-14,230	-
	All bit.	14,210	12,000-14,440	14,350
Washington	High-vol. bit.	11,550	10,350-12,190	11,900
	Subbituminous	8,370	7,970- 8,720	
West Virginia	Low-vol. bit.	14,380	13,060-14,760	-
	Med.-vol.bit.	14,410	13,450-14,890	-
	High-vol. bit.	13,720	12,420-14,670	-
	All bit.	13,950	12,420-14,890	14,200
Wyoming	High-vol. bit.	11,680	10,290-12,650	11,610
	Subbituminous	9,020	7,840- 9,530	
All United States ...	All coal	13,000	-	-

1 -Values calculated for this paper.

2 -Mechanization, Employment, and Output per Man in Bituminous Coal Mining: W.P.A. Report No. E-9, vol. I, 1939, p. 53.

*Range of county averages, except for Pennsylvania anthracite, where range is by regions.

**Based upon representative analyses of mine samples only.

COMPILATIONS OF COAL ANALYSES FOR SALE BY GOVERNMENT PRINTING OFFICE

(As of April 1, 1949)

Bureau of Mines Technical Papers:

No.	Name
347	Analyses of Alabama Coals
682	Analyses of Alaska Coals
416	Analyses of Arkansas Coals
574*	Analyses of Colorado Coals
641	Analyses of Illinois Coals
417*	Analyses of Indiana Coals
269*	Analyses of Iowa Coals
455	Analyses of Kansas Coals
308*	Analyses of Kentucky Coals
652	Analyses of Kentucky Coals
465	Analyses of Maryland Coals
366	Analyses of Missouri Coals
529	Analyses of Montana Coals
569	Analyses of New Mexico Coals
344	Analyses of Ohio Coals
411*	Analyses of Oklahoma Coals
590	Analyses of Pennsylvania Bituminous Coals
645	Supplement to No. 590
659	Analyses of Pennsylvania Anthracitic Coals
356*	Analyses of Tennessee Coals
671	Analyses of Tennessee Coals (Including Georgia)
345	Analyses of Utah Coals
365*	Analyses of Virginia Coals
656	Analyses of Virginia Coals
491*	Analyses of Washington Coals
618	Supplement to No. 491
405*	Analyses of West Virginia Coals
626	Analyses of West Virginia Coals
484	Analyses of Wyoming Coals
696	Analyses of Arizona, California, Idaho, Nevada, and Oregon Coals
700	Analyses of Michigan, North Dakota, South Dakota, and Texas Coals

* Out of print but available for reference in many technical and public libraries.

Typical Analyses, Bituminous Coal:

Data Book, Vol. 1	Districts 7 and 8: Southern W. Va., Va., Eastern Ky., Tenn., and N. Car.
Data Book, Vol. 2	District 1: Eastern Pa., Md., and W. Va.
Data Book, Vol. 3	Districts 2, 3, 4, 5, and 6: Western Pa., Northern W. Va., Ohio, and Mich.
Data Book, Vol. 4	District 13: Ala., Ga., and Tenn.
Data Book, Vol. 5	Districts 10 and 11: Ill. and Ind.
Data Book, Vol. 6	District 9: Western Ky.
Data Book, Vol. 7	Districts 12, 14, and 15: Iowa, Ark., Kans., Mo., Okla., and Tex.
Bulletin 446	Typical Analyses, United States and Alaska.